THE ROLE OF HYDROGEN IN HEATING BUILDINGS

Executive summary of a study for Viessmann Climate Solutions (translation of German original)

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SUMMARY

Climate-neutral heat supply requires a considerable transformation of the heat sector; Germany targets a reduction in CO_2 emissions from the heat market of at least 40 % by 2030

The generation of space heating and hot water in the building sector (referred to as "heat market" in this study) plays a central role in achieving Germany's climate targets. By 2030, CO_2 emissions are to be reduced by 40% compared to today. In light of the recent tightening of the EU CO_2 reduction targets in the context of the EU Green Deal, a further increase in efforts in the heat market in Germany is to be expected. For comparison, in the last decade CO_2 emissions were only reduced by 18%.

Hydrogen is recognised as an important component for achieving climate neutrality, therefore a rapid market ramp-up is now key

At the same time, the public debate now recognises that renewable or low-emission hydrogen is a central building block in achieving climate goals. The EU has set itself the goal of building 40 GW of electrolysis capacity for the production of renewable electricity based hydrogen by 2030. Germany alone wants to build up to 5 GW by 2030, and 10 GW by 2040 at the latest.

Both the German Hydrogen Strategy as well as the long-term Renovation Strategy of the German government refer to the use of hydrogen to decarbonise the heat market.[1] However, various stakeholders are arguing for hydrogen use to be restricted to the industry and the transport sector for the following reasons:

- insufficient availability of hydrogen for all sectors (hydrogen as a "scarce commodity");
- better alternatives than hydrogen for decarbonisation in the heat market, particularly by increasing the energy efficiency of buildings ("building envelope") and increasing the energy efficiency of heating systems, especially in the form of electric heat pumps; and
- lack of technical or economically viable alternatives to hydrogen for decarbonising applications in some industries, and for some modes of transport such as long-haul air and sea transport.

Result of the study: In practice, the use of hydrogen in the heat market can both meaningfully support the decarbonisation of the heat market and promote the general hydrogen market ramp-up.

In this study, we elaborate on factors that, in our opinion, are given too little weight in the current debate on the decarbonisation of the heat market:

[1] For example, in the National Hydrogen Strategy (BMWi 2018): "In the long term, hydrogen and its derived products can contribute to the decarbonisation of parts of the heat market in various ways".

- **Heterogeneity of the heat market - Hydrogen can complement energy efficiency measures and the direct use of renewable energies in a useful way (Section 2)** - The focus of policy makers on significantly improving energy efficiency (of building shells and heating systems) abstracts from the heterogeneity of the building stock and resulting technical and economic limits of efficiency improvements. 89% of today's building stock is more than 20 years old, while only 13% are new buildings or considered fully refurbished. About 90% of heating systems in the building stock are gas or oil-based appliances. There is no "one-size-fits-all" solution to decarbonise this existing building stock.

  A one-sided focus on energy refurbishment in conjunction with electric heat pumps also ignores the considerable practical hurdles to achieve high refurbishment rates. For example, in order to realise the German government's target of a 2% annual energy refurbishment rate, the craftsman sector would have to carry out twice as many refurbishments annually in the next 10 years comparted to the last 20 years, during which the refurbishment rate has been continuously below 1% despite considerable political efforts to increase it. This does not seem realistic, given that the capacity utilisation of craftsmen is already at a very high level, for example at around 90% in the construction sector. Further, the number of available craftsmen is expected to decline as a result of demographic change; apprentices in the German craftsmen sector have fallen by 40% in the last 20 years. In addition, there are numerous practical hurdles at the household level, which lead to lower than targeted energy refurbishments.

  In view of the high urgency with which climate protection contributions must be achieved in the heat sector, further technology paths for reducing emissions must be developed. Hydrogen-based renewable or climate-neutral gases can make a valuable contribution here and provide important options for decarbonising the heat market. Depending on progress in energy efficiency and the market penetration of alternative technologies, the demand for hydrogen will be lower than the current share of natural gas in heat supply.

- **Production volumes – Hydrogen in the heat market helps to meet the challenge of limited renewable energies in Germany and can also support the market ramp-up of hydrogen in other sectors (Section 3)**. Covering the entire energy demand through renewable energies would require an increase in production of electricity from wind and photovoltaic by a factor of 3 to 10 (from less than 200 TWh per year today). This is unlikely to be achieved by domestic renewable energy locations in a socially acceptable manner. Worldwide, however, there is considerable potential for renewable energies, which greatly exceeds future energy demand. Germany's considerable gas import capacities – about 2,800 TWh of natural gas can be imported per year via pipelines alone – can be used to import renewable energies via hydrogen or hydrogen-based gases from regions with better climatic or geological conditions.[2] Hydrogen is therefore by no means scarce in the (longer-term) future.

What is missing, however, is a reliable demand for hydrogen and corresponding investment incentives for the market ramp-up of hydrogen and hydrogen-based gases. The heat market could provide such a stable demand for hydrogen in the short term. Already today, the heat market can absorb 10 TWh of hydrogen directly through hydrogen blending – this corresponds to about 70% of the German government's volume target for domestic production of renewable hydrogen in 2030. Moreover, those volumes can be significantly increased through the installation of "H2-ready" appliances in the foreseeable future. In this way, the heat market can provide demand security for investments in hydrogen production, transport and distribution, and in this way support the market ramp-up of hydrogen in the other sectors.

- **Seasonality – Hydrogen can help to serve the significant seasonality of demand in the heat sector (Section 4)**. Energy demand in the heat market is characterised by considerable seasonality of demand, plus rare periods of extreme cold ("1 in 20 winters") during which heat supply must be secured. While the gas infrastructure has been constructed in a way to fulfil those demand characteristics and can be adapted to increasing hydrogen shares, such peak load provision through the electrification of heating systems represents an enormous challenge for the power system. This is despite the high energy efficiency of heat pumps and gradually improved thermal insulation in existing buildings.

  For example, with the help of its 260TWh gas storage volumes, the gas infrastructure in Germany can meet gas demand for up to three months from storage alone, which already serves a gas consumption profile that is about three times as high in the peak month in winter (usually January or February) as in the off-peak month in summer (usually July or August). So far, the electricity system in Germany has to deal with only 1.2 times the peak as off-peak monthly consumption, and electricity storage volumes are correspondingly only about one 6,000th of gas storage volumes. Electrification of heat demand by 5 million additional heat pumps in 2030 would lead to an increase in peak load of 12 to 45 GW (equivalent to 15 to 55% of today's system peak load of about 80 GW). With the simultaneous decommissioning of 36 GW of electricity generation capacity (equivalent to approx. 35% of today's secured capacity) as a result of nuclear and coal phase-out by 2030, this represents a considerable challenge for the security of supply of electricity.

- **Transport – The existing gas infrastructure can support the transport of renewable energy to heat consumers via hydrogen (Section 5)** - Renewable energy does not necessarily occur where heat is consumed. Some heat demand can be sensibly served by decentralised renewable energies such as solar thermal energy (possibly via district heating) or photovoltaics in combination with electric heat pumps. However, a considerable proportion of heat demand will need to be served by onshore and offshore wind energy in

[2] Although capacities change when switching from natural gas to hydrogen (e.g. due to differences in energy density and flow velocity), pipelines are assumed to have energy transport capacities of a similar order of magnitude to natural gas, see Siemens Energy, Gascade and Nowega (2020), page 10ff.

the long term. Wind energy production mainly occurs in the north of Germany and must be transported to the centres of consumption in the south and west of Germany. In the current draft of the Network Development Plan (NEP) of 11 February 2021, for example, the transmission system operators estimate that in 2035 there will be a considerable generation surplus in the northern and eastern German states with a simultaneous considerable import demand in southern and western Germany. They estimate that by 2035 investment costs of over 100 billion euros (existing network and expansion of network) will be required for onshore electricity transmission lines alone.

Due to the historical transport task of transporting gas from production and import areas in north/east to consumption centres in south/west, the existing gas infrastructure has extensive transport capacities. For example, the transport capacity in the north/south axis amounts to about a factor of 4 of the electricity transport capacity. In addition, the extensive gas distribution network reaches about 50% of all household customers and the majority of industrial and commercial customers. Accordingly, the gas infrastructure can make a valuable contribution to the decarbonisation of the heat market by transporting hydrogen produced from (green) electricity from generation to the end consumer via the existing gas grid.

- **Costs – The use of hydrogen can reduce total system costs of decarbonisation in the heat market and reduce the financial burden on (especially low-income) households (Section 6)** – The use of hydrogen-based or climate-neutral gases in the heat market can optimise the total system costs of decarbonisation. System costs take into account the implications of the choice of the heating system on energy supply (or energy conversion), energy transport, energy distribution and energy storage, purchase and maintenance of the heating systems themselves, as well as energy refurbishments measures. Studies analysing the minimum total cost technology mix in the heat market are, however, heterogeneous. For example, ten studies released in the last four years identify different shares of gas (including hydrogen) in the German total energy demand in 2050 as economically optimal – ranging from almost 0% to as high as 50%. Accordingly, there is a need for further research here.

  The fact that different studies predict very heterogenous levels of optimal shares of hydrogen – just like the heterogeneity of the building stock – is an argument in favour of keeping a large number of technological options open through today's political decisions. Policy makers should not bet only on one or a few technology options today and exclude other options such as the installation of gas heating systems, as in the future these can increasingly be served with renewable gas, e.g. based on hydrogen.

  In addition to the overall cost perspective, a strong focus on refurbishment and electrification disproportionately affects low-income population groups due to the high investment costs incurred upfront ("share of wallet"). Therefore, the preservation of options such as hydrogen in the heat market can potentially help to achieve the decarbonisation of the heat market in a more socially acceptable way.

Conclusions: The policy framework must ensure that hydrogen can contribute to efficient decarbonisation of the heat market (Section 7)

Decarbonising the heat market poses major challenges for the energy system with respect to generation, storage and transport. This must be considered in the overall system when making policy decisions with implications for certain technologies. Partial analyses, for example of energy efficiency alone, do not meet this requirement. Moreover, "the heat market" is extremely heterogeneous, so there are no sensible "one-size-fits-all" solutions. Instead, a balanced mix of energy sources and technologies is required. Hydrogen and climate-neutral gases can make a valuable contribution to meeting the challenges of decarbonisation, especially due to their good storability, transportability and thus also importability, and should be part of the future energy carrier mix. This also includes the heat market, which can absorb large quantities of hydrogen on short notice without additional expenses by blending hydrogen into the existing gas grid. Therefore, the heat market can also support the desired market ramp-up of hydrogen in the short term through a secure demand for hydrogen. If hydrogen is to be made available to industrial and commercial customers with a gas connection in the distribution network – which includes more than 99% (1.8 million) of industrial and commercial customers with a gas connection in Germany, while only 500 industrial and commercial customers are directly connected to the transmission network – household gas consumers must be made "H2 ready" in any case.

However, there is still a need for more research, which is not surprising given the rapid development in the discussion around green hydrogen in recent years. In light of the above, precedents must not be created today that exclude decarbonisation options that could very likely still make valuable contributions.

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